PRACTICE OBSERVED

Practice Research

Duration of effectiveness of pertussis vaccine: evidence from a 10 year community study

DOUGLAS JENKINSON

Abstract

A 10 year study of whooping cough in a discrete general practice community was performed to assess longitudinally the efficacy of pertussis vaccine from one to seven years after immunisation. Of the 436 cases of whooping cough over 10 years, 326 occurred in children aged 1-7 years. The rate of immunisation was known for each cohort of children born during each year, and the attack rate of whooping cough was thus calculated for those immunised and unimmunised. The attack rates were highest in those cohorts exposed to the epidemics of 1977-9, 1981-3, and 1985-7. The efficacy of the vaccine was calculated as a percentage as (attack rate in unimmunised group—attack rate in immunised group) × 100/attack rate in unimmunised group. It fell from 100% in the first year to 46% in the seventh, being 84% in the fourth and only 52% in the fifth.

Thus the pertussis vaccine or its schedule of use does not seem to provide sufficient herd immunity to prevent outbreaks of whooping cough. Matters might be improved if vaccination against pertussis were included in the preschool immunisation programme.

Department of General Practice, University of Nottingham

DOUGLAS JENKINSON, FRCGP, DCH, lecturer

Correspondence to: Keyworth Health Centre, Keyworth, Nottingham NG12 5JU

Introduction

Pertussis vaccine is acknowledged as being effective in reducing the incidence of whooping cough in the United Kingdom.[1] The many attempts to measure its effect have produced widely differing figures for its efficacy and little information about the duration of its effect, and all studies have been cross sectional.[2-10] My study of whooping cough in a discrete general practice community over 10 years enabled me to measure the duration of effectiveness of pertussis vaccine longitudinally.

Patients and methods

From August 1977 to July 1987 I identified, observed, and recorded the course of 436 cases of whooping cough in the Keyworth group practice. The practice comprises 11 500 patients and four doctors, is semirural, and is the only one in the area. The population is comparatively prosperous and static, with more people in social classes II and III than the national average.

Whooping cough was diagnosed clinically and based on at least three weeks of characteristic paroxysmal coughing, usually associated with vomiting and often whooping.[7 11 12] Bacteriological confirmation was sought when possible. Pernasal swabs were taken from 207 patients; 96 (46%) swabs were positive for bordetella, 94 for *B pertussis* and two for *B parapertussis*. The rate of immunisation with triple vaccine has been known for each cohort of children born during each year after 1972 as a child health clinic has always functioned in the practice. Before 1972 all primary immunisations included vaccination against pertussis and the rate of immunisation was believed to be 95%.

Although schedules for vaccination against pertussis changed from being completed at the age of 13 months to being completed at the age of 11 months during the study, no immunised child younger than 1 year developed whooping cough and no child older than 1 year developed whooping cough before a schedule was completed. Thus counting the number of patients with whooping cough from the age of 1 year exactly caused no distortion.

Inevitably patients moved away during the 10 years of the study so that some contamination of the original cohorts occurred. It is, however, a fairly

static community, which is shown by the fact that 125 of the 162 (77%) patients who had whooping cough in 1977 are still registered with the practice. As it was not possible to establish an accurate history of the disease or immunisation with pertussis vaccine in new patients joining the practice I have assumed that the patients who left the practice were replaced by the same number of patients joining and that the same proportions of them were immunised against and previously affected by whooping cough. To estimate the possible error caused by this assumption I assessed the rate of change in the population of the age group studied from a sample over eight years. The mean rate of change was 7% a year, and the population also increased by 3% a year. The rate of immunisation against pertussis in this practice has always been higher than that in the nation overall, the rate in incoming patients being similar to that nationally.

TABLE I—*Numbers of children aged 1-7 years affected by whooping cough by year of birth and state of immunisation against pertussis; numbers of unaffected children are given in parentheses. Cumulative attack rates by age are also given for immunised and unimmunised children*

Year of birth	Immunisation against pertussis	Age (years) 1	2	3	4	5	6	7
1970	+							9 (210)
	−							0 (10)
1971	+					2 (188)	10 (186)	1 (176)
	−					0 (10)	1 (10)	0 (9)
1972	+				1 (189)	20 (188)	0 (168)	0 (168)
	−				0 (10)	4 (10)	0 (6)	0 (6)
1973	+			1 (114)	12 (113)	1 (101)	0 (100)	0 (100)
	−			4 (64)	12 (60)	0 (48)	0 (48)	1 (48)
1974	+		1 (95)	6 (94)	1 (88)	0 (87)	0 (87)	0 (87)
	−		0 (84)	36 (84)	8 (48)	2 (40)	1 (38)	1 (37)
1975	+	0 (85)	1 (85)	1 (84)	0 (83)	1 (83)	3 (82)	1 (79)
	−	1 (70)	21 (69)	5 (48)	1 (43)	1 (42)	4 (41)	0 (37)
1976	+	0 (42)	0 (42)	0 (42)	0 (42)	0 (42)	0 (42)	0 (42)
	−	24 (92)	3 (68)	7 (65)	1 (58)	3 (57)	2 (54)	0 (52)
1977	+	0 (42)	0 (42)	0 (42)	1 (42)	0 (41)	0 (41)	0 (41)
	−	2 (53)	0 (51)	3 (51)	5 (48)	3 (43)	0 (40)	0 (40)
1978	+	0 (83)	0 (83)	1 (83)	0 (82)	0 (82)	5 (82)	1 (77)
	−	2 (54)	3 (52)	6 (49)	3 (43)	0 (40)	4 (40)	3 (36)
1979	+	0 (79)	0 (79)	0 (79)	0 (79)	1 (79)	2 (78)	2 (76)
	−	1 (52)	3 (51)	1 (48)	0 (47)	0 (47)	4 (47)	3 (43)
1980	+	0 (94)	0 (94)	0 (94)	0 (94)	3 (94)	4 (91)	1 (87)
	+	3 (20)	1 (17)	0 (16)	0 (16)	3 (16)	3 (13)	0 (10)
1981	+	0 (95)	0 (95)	3 (95)	1 (92)	1 (91)	3 (90)	
	−	0 (20)	0 (20)	0 (20)	6 (20)	3 (14)	1 (11)	
1982	+	0 (113)	1 (113)	2 (112)	0 (110)	0 (110)		
	−	0 (17)	0 (17)	0 (17)	2 (17)	0 (15)		
1983	+	0 (83)	0 (83)	0 (83)	0 (83)			
	−	1 (10)	2 (9)	2 (7)	0 (5)			
1984	+	0 (98)	0 (98)	2 (98)				
	−	0 (9)	0 (9)	3 (9)				
1985	+	0 (81)	0 (81)					
	−	0 (19)	0 (19)					
1986	+	0 (91)						
	−	1 (6)						
Total	+	0 (986)	3 (990)	16 (1020)	16 (1097)	29 (1186)	27 (1047)	15 (1143)
	−	35 (422)	33 (466)	67 (478)	38 (415)	19 (382)	20 (348)	8 (328)
Attack rate	+	0	0·003	0·016	0·015	0·024	0·026	0·013
	−	0·083	0·071	0·140	0·092	0·050	0·057	0·024

TABLE II—*Rates of immunisation with pertussis vaccine and attacks of whooping cough in children aged 1-7 years by year of birth*

Year of birth	Rate of immunisation (%)	Attack rate (%)
1970	95	4
1971	95	7
1972	95	13
1973	64	17
1974	53	31
1975	55	26
1976	31	30
1977	40	15
1978	60	20
1979	60	13
1980	81	16
1981	83	16
1982	86	4
1983	89	5
1984	91	5
1985	81	0
1986	94	1

TABLE III—*Efficacy of pertussis vaccine in children by age*

Age (years)	1	2	3	4	5	6	7
Efficacy of vaccine (%):	100	96	89	84	52	54	46

The efficacy of the vaccine was calculated for each year of age by reducing the immunised and unimmunised groups in each birth year cohort by the number of patients affected in each year, the remainder becoming the cohort at risk in the next year of age, and so on. Sufficient patients aged 1 to 7 years developed whooping cough to allow the affected and unaffected groups to be summed for 11 or 12 consecutive years of exposure. Each age group, although being exposed and born in different years, was therefore treated as a single population for the purpose of the calculation. The attack rates were calculated for immunised and unimmunised groups, and the efficacy was expressed as a percentage in the standard way—that is, (attack rate in unimmunised group—attack rate in immunised group)×100/attack rate in unimmunised group.

Results

Altogether 326 cases of whooping cough occurred in children aged 1-7. For most patients the probable source of infection could be identified and was usually family, nursery, or school. Table I shows the sizes of the immunised and unimmunised groups in each cohort, the numbers affected by whooping cough, and the cumulative attack rates. The pattern of attack by whooping cough for each birth year cohort can be seen by looking from left to right across table I. Those cohorts exposed to the three epidemics of 1977-9, 1981-3, and 1985-7 from a young age had the highest attack rates. Table II shows the rates of attack and immunisation in 1 to 7 year olds for

each birth cohort from 1970 to 1986. Table III shows the efficacy of pertussis vaccine in children aged 1-7.

Discussion

Pertussis vaccine, in common with other killed whole cell vaccines such as typhoid and cholera, causes more reactions and is less effective than most toxoid or live vaccines such as tetanus or polio. Vaccination against pertussis is also the only immunisation for infants that is not reinforced when children first attend school. The policy for immunisation seeks to protect infants from exposure to whooping cough by giving older siblings and their peers individual protection. If this protection remains high until the natural susceptibility to the disease is low transmission cannot occur and herd immunity exists, as is presently the case for diphtheria and polio. The level of immunisation in the community achieved in this country before 1973 (about 80%) reduced the incidence of whooping cough considerably,[1] but outbreaks still occurred every four years and appreciable herd immunity probably did not exist. Even if the target rate of immunisation of 90%[13] were achieved outbreaks might still occur.

Many cases of whooping cough are not notified[14] and others are missed as it is often a mild illness.[15] These factors account for the fact that the incidence in this practice is about eight times the national rate of notification. Bacteriological confirmation in 46% of swabs taken was better than that achieved in other studies, and therefore many false positive diagnoses were unlikely. A specific search for subclinical infection in this practice in 1985 confirmed the improbability of false negative results.[12]

My results suggest that the efficacy of pertussis vaccine is complete only for the first year after immunisation and falls gradually over the next three years, although by the fourth year it is still 84% effective. During the next three years efficacy is around 50%, which is probably not adequate. Most infants who acquire whooping cough do so from older siblings who are infected at school. If infants are to be adequately protected their siblings' immunity should probably be kept high at least through primary school. The fact that no carrier state is thought to exist in infection with pertussis and that the infection is species specific suggests that whooping cough could be eradicated.[16] The seemingly rapid decline in the efficacy of the vaccine after the fourth year suggests that such an objective is probably unattainable with the current vaccine.

Previous studies were cross sectional and therefore took no account of the possibility of previous infections with whooping cough. Those studies in the United Kingdom that related the effectiveness of the vaccine to age[2,4,5,9] found a small diminution with time[2,4,5]; they mostly looked at the first five years of life and found protection to be between 80% and 90%. Other studies of the efficacy of pertussis vaccine did not look at rates specific to age but combined various age groups and found rates between 38% and 68%.[3,6,7] A small study in Kent County, Michigan, showed a fairly rapid diminution of efficacy that was related to the time since immunisation irrespective of the age at which the vaccine was given.[10] Variation among studies must be the result of differences in vaccines, methods of diagnosis, knowledge of previous disease, numbers of missed cases, patients' susceptibility to respiratory problems, and other unrecognised factors in addition to the decay of the vaccine's effect. The lack of agreement among these previous studies may be partly explained if the decay in efficacy is as rapid as this study suggests as overall efficacy will be affected by the age range of the population studied. Although this study did not eliminate all the possible confounding factors, its longitudinal nature, the age specificity of the results, the discrete community, and the fact that it was done by a single observer reduced many of them.

The calculation of efficacy assumes no change in the population. This is clearly not the case, but the effect of probable changes can be estimated. The rate of immunisation against pertussis in this practice has always been higher than that in the nation overall, the rate in incoming patients being similar to that nationally. The effect of this would be to decrease the number of immunised children remaining in the practice and increase the number of unimmunised children in each successive year. The result is a higher attack rate in the immunised and a lower attack rate in the unimmunised children, giving an even steeper fall in efficacy. A recalculation allowing for these possible changes resulted in a fall from 100% to 37% rather than 46% over the seven years.

It may not be of much consequence for the individual child of school age if the vaccine fails to protect him or her, but it may be important for a young infant at home. A programme of vaccination against pertussis needs to be capable of achieving good herd immunity, and the present vaccine or its schedule of use does not seem to be achieving it. Consideration might be given to including vaccination against pertussis in the preschool immunisation programme.

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ONE HUNDRED YEARS AGO

According to the law of China, the punishment inflicted on the murderer of a father, mother, brother, husband, uncle, or tutor, and on traitors, is that appalling process known as *ling-chie*, or slow death. The fact that the crime has been committed under the influence of insanity procures no mitigation of the dread sentence, and the miserable culprit is sentenced to be cut into 24, 36, 72, or 120 pieces, a large proportion of which must be accomplished ere the executioner dares to touch a vital part, and end the torture of the victim. Only in certain cases does the Imperial clemency grant death after the eighth division. The commonest form of this penalty is that of twenty-four cuts; and the executioner prides himself on the anatomical skill with which they are administered. The victim being bound to a cross, the butcher by the first two cuts removes the eyebrows, by the third and fourth the shoulders, the fifth and sixth the breasts, the seventh and eighth the flesh of the forearm, the ninth and tenth the flesh of the arm, the eleventh and twelfth the flesh of each thigh, and so on.

(*British Medical Journal* 1888;i:150)